Declass Review by
NIMA/DOD

25X1A

VSH-MX-002-2

25X1A

[redacted]

ENGINEERING REPORT NO. 8928

EQUAL MAGNIFICATION GEMS STUDY

25X1A [redacted]

FINAL REPORT

DATE: 7 Sept. 1967

25X1A

PREPARED FOR: [redacted]

[redacted] 25X1A

25X1A

[redacted]

VSH-MX-002-2

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ABSTRACT

Earlier GEMS efforts substantiated the fact that the appropriate program mission material could not be simulated from an original negative that was processed to a high gamma and/or photographed under conditions that introduced either a siginficant amount of atmospheric haze or a compressed scene exposure range. The Equal Magnification GEMS Study was initiated to investigate the properties that a transparency must possess to yield a valid simulation and the proper technique of performing the simulation.

The study report treats all phases of the simulation topic. It clearly defines the system parameters to be simulated and uses these parameters as guides in developing the overall aspects of a total procedure which will yield appropriate and realistic simulated photographs. The findings of this study represent the ground work for future effort requiring system GEMS matrices.

SECTION I

EQUAL MAGNIFICATION GEMS INVESTIGATION

1.1 INTRODUCTION

The photographic simulation technique requires the use of a positive transparency that possesses certain photographic characteristics.[1] In the simulation of modulation transfer function (MTF), exposure and contrast, it is essential that the positive transparency is of higher quality than the desired GEMS with respect to these parameters.

When simulating a photographic system, it is necessary to analyze the requirements placed upon the positive transparency by the simulation process and by the particular system parameters in order to determine what constitutes a suitable transparency. Such an analysis was performed, in this study, for the appropriate system related to this program.

1.1.1 Statement of Problems

The present simulation technique requires the use of a unity gamma, positive transparency in a modified contact printer arrangement. The unity gamma, positive transparency is essential if the simulation of MTF is to be both predictable and controllable. Problems develop when attempting to obtain a realistic simulation from negative material that is unsuitable for the simulation process.

The normal simulation process has involved the selection of an original negative with desired scene content, exposure range, image contrast, 25X1A

Approved For Release 2002/06/17 : CIA-RDP78B04747A000700010026-6

and resolution; reproduction of the negative to obtain a master transparency with a cascaded gamma of unity; and printing of this master on the modified contact printer to generate GEMS. The problems become evident when considering the processing tone reproduction cycle of the simulation process. If the original material received processing corresponding to a gamma of 2.3, the cascaded unity gamma specification placed upon the master transparency dictates that the positive be processed to a gamma of approximately 0.43.

In the 0.43 gamma, positive transparency processing step, the contrast of the imagery as well as the exposure range is greatly reduced. The possibilities are high that this reduction is in excess of the parameter specification for the best GEMS; especially, if the negative material was originally obtained at an altitude where atmospheric haze will influence the contrast of the resulting imagery. The contrast of the film imagery can be increased by increasing the processing gamma of the negative GEMS; but then, the tonal simulation would no longer be valid. In addition to reducing the exposure range and imagery contrast, the 0.43 gamma processing also serves, in a cascading type effect, to introduce a serious loss in resolution.

1.1.2 Statement of Study Objectives

To insure a successful equal viewing magnification simulation of the appropriate system, the principal objectives of the study were directed toward:

(a) defining the parameters to be simulated,

(b) investigating and specifying the equipment requirements to assure proper simulation of system parameters, and

(c) determining and specifying means of acquiring original material that will permit realistic simulations of all system parameters.

1.2 SPECIFICATION OF SYSTEM PARAMETERS

In order to properly simulate the performance of a photographic system, it is necessary to examine all aspects of the simulation process in relationship to the system parameters. The parameters of primary interest to this study are:

(a) system MTF

(b) imagery contrast

(c) scene exposure

(d) film tonal scale

The simulation capabilities should account for future improved system performance, the best conditions of contrast and exposure, and typical processing characteristics of type 3404 film. For this reason, the parameter ranges, as determined in the System Parameters Study, [redacted] 25X1A have been extended for this investigation. The system parameter requirements, to be met in the simulation process, are as stated below:

(a) The MTF will cover a spatial frequency range of 150 cycles per millimeter.

(b) The film imagery contrast will have a maximum average modulation of 0.50; and the maximum modulation for normal film imagery will be 0.94. It is to be noted that highly reflective ground objects will product modulations greater than 0.94.

(c) The scene exposure will have a maximum density range of 2.5 for any type ground object.

(d) The characteristic curve, that is representative of mission material processed film, will be simulated in the GEMS processing. (See Figure 1).

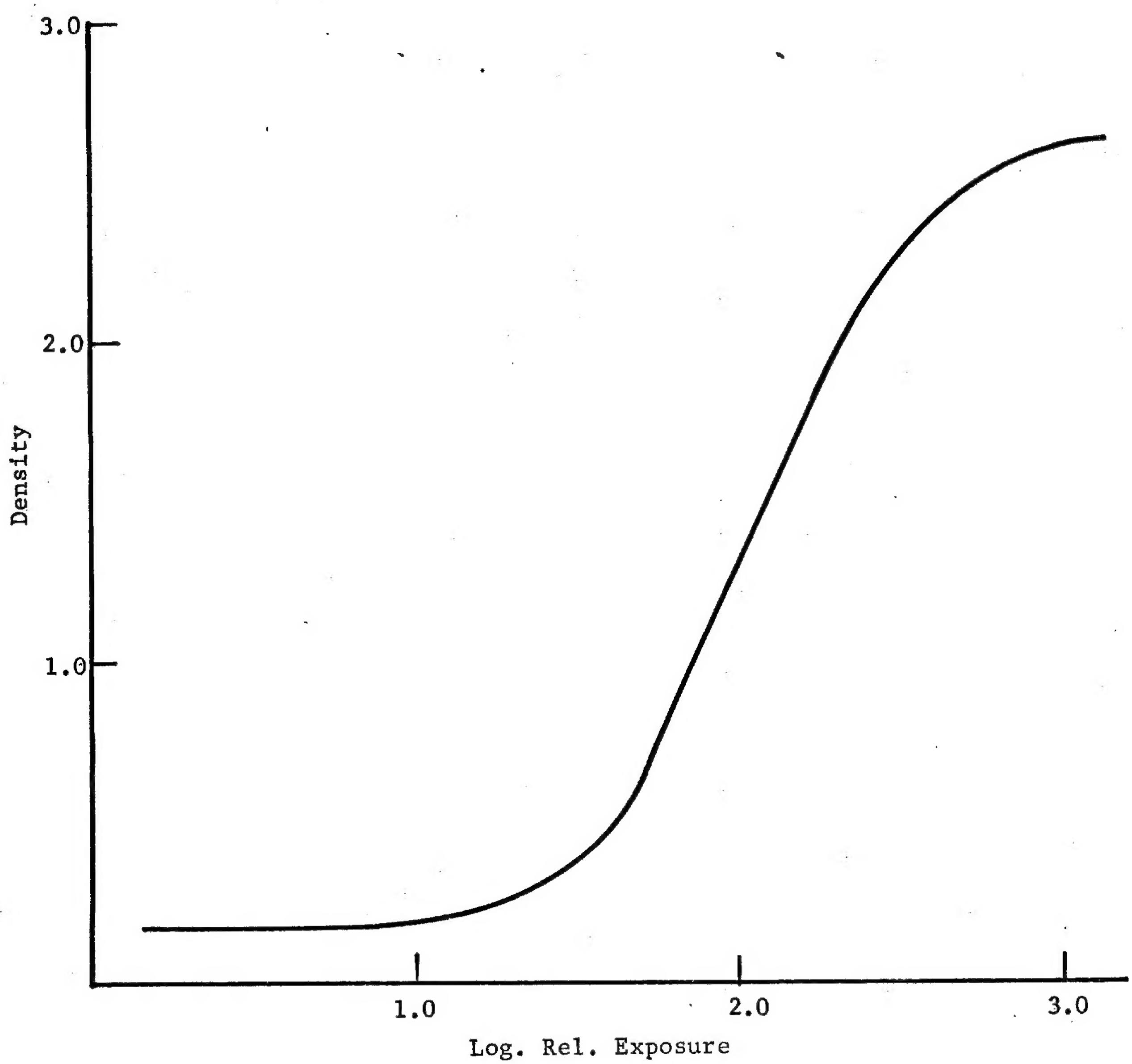

Figure 1. Plot of System Processing Characteristic Curve

SECTION II

ANALYSIS OF SIMULATION PROCESS

2.1 GENERAL DISCUSSION OF SIMULATION PROCESS

The general simulation theory of convolving spread functions in a linear fashion is most valid and highly predictable and controllable. Since the ease of predictability and controllability of the spread function is a most desirable simulation feature, all other potential schemes for controlling the non-linear convolution of spread functions in this process will be exempted from consideration.

The spread function simulation process requires that the transmission of the master transparency be linearly proportional to exposure. This requirement dictates that the transparency employed must be a positive with a cascaded gamma of unity. For, only over the linear portion of such a transparency characteristic curve will the convolution of the spread functions be valid.

The above requirements make it imperative to define a film-processing combination that will yield a transparency with a linear characteristic curve. In addition, the resolution of the film, the contrast of the imagery, and the exposure range of the scene must be compatible with the simulation process and the parameter specifications of the best GEMS.

Very little has been stated about duplicating the film properties of the mission material. One ground rule to be established at the outset of this analysis is that the GEMS will be generated on type 3404 film. Use of the mission type film will provide reasonable assurance that the desired film characteristic curve, the film grain, and the imagery neutrality requirements will be met in the simulation process.

2.2 MASTER TRANSPARENCY REQUIREMENTS

Most of the master transparency requirements have been implied or specified in Paragraphs 1.2 and 2.1, above. It will be sufficient to state that the master transparency, film imagery contrast requirements will be met by the taking of photography at low altitudes. In addition, the technique of obtaining the master transparency will be such that the density range of the transparency will be compatible with the exposure range of type 3404 film.

2.3 SIMULATION EQUIPMENT REQUIREMENTS

Analysis of the simulation technique for controlling MTF in the modified contract printer has indicated that the technique is Fresnel diffraction limited at approximately 100 cycles per millimeter. This implies that the simulation of MTF values is not accurate for the spatial frequency region above this point. The system parameter specifications clearly state that the MTF simulation capabilities must cover a spatial frequency range of 150 cycles per millimeter.

Over the system spatial frequency range described, control of the MTF can be accomplished with the use of a modified copy camera. This proposed concept, for controlling MTF, was initially investigated under the Alternate GEMS
25X1A Technique, [redacted] Experimentation was performed under this task to demonstrate that the concept is valid and "that the only limitation was in the optics and not in the theories or techniques utilized."

The equipment to be established for the control of MTF would take into account the design of better optics and the use of aberration plates instead of apodizing masks. Figure 2 represents a simplified diagram of the equipment. The lens system would operate at approximately a 20:1 conjugate to permit the use of a master transparency with as limited an MTF as 50 cycles per millimeter.

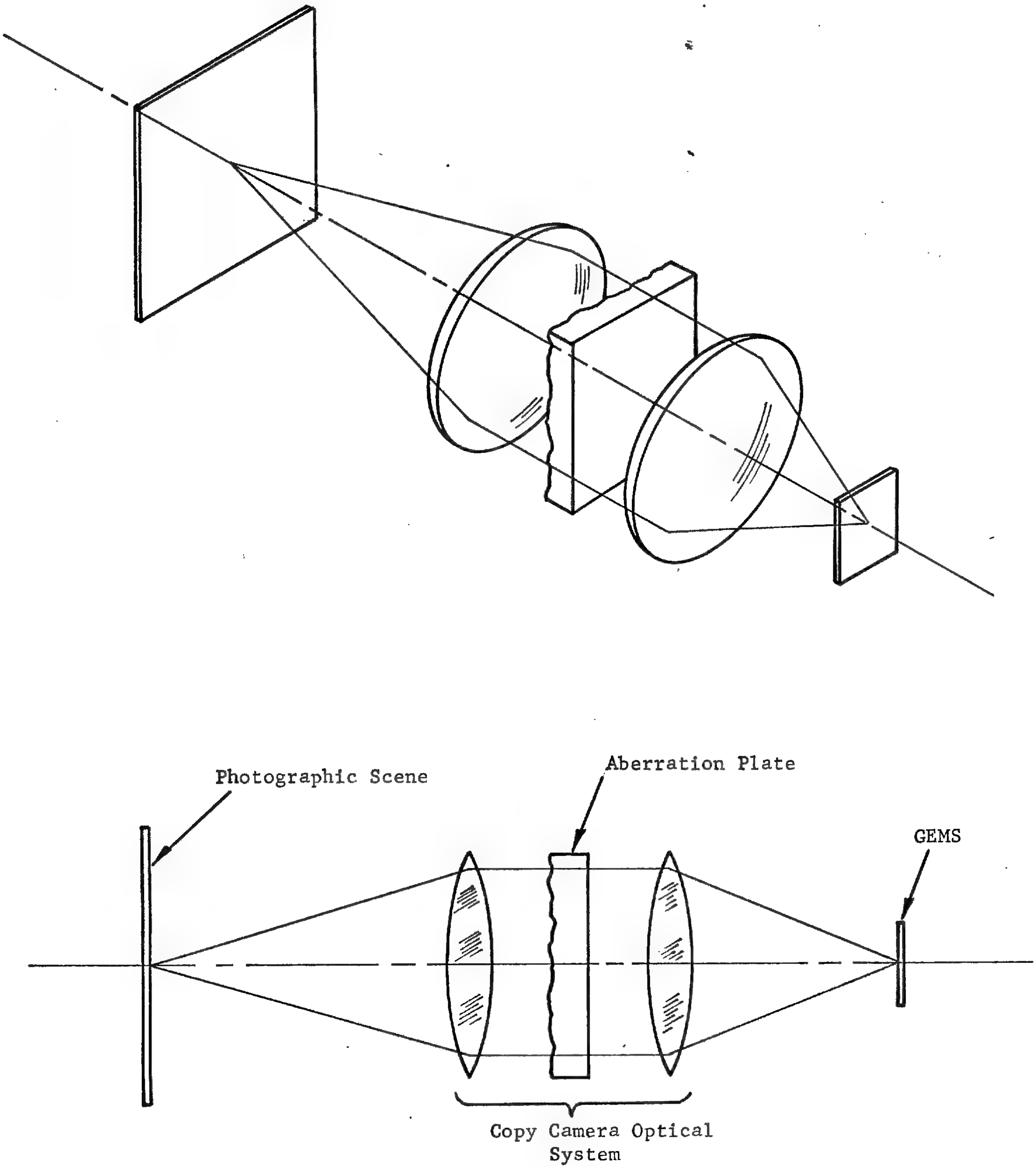

Figure 2. Modified Copy Camera

This high reduction factor will virtually eliminate the effective printing grain size of the transparency film and also ensure that the spatial frequency range of 150 cycles per millimeter is achievable.

The use of aberration plates for the control of MTF shape and spatial frequency extent was first suggested for use in the Pseudo GEMS Viewer. By employing aberration plates, the problems associated with apodizing masks are eliminated, the costs of MTF control are far less, and the transmission of the optical system is substantially increased to permit very short exposure times.

As a note of worthy importance, it should be stated that the simulation techniques of exposure and contrast, established for the modified contact printer process, are directly applicable to the modified copy camera approach.

SECTION III

FILM INVESTIGATION

3.1 FILM STUDY

Before discussing the details of the film study, it would be advantageous to clearly define the study objectives. The prime purpose of the film study is to investigate conventional and unconventional, silver and non-silver photographic systems which might yield the following desirable master transparency characteristics:

(a) A cascaded, unity gamma, positive transparency whose characteristic curve represents a linear relationship for practically the entire density-exposure range of the film.

(b) A film density range compatible with the exposure range of type 3404 film.

(c) Image quality which is at least 50 cycles per millimeter.

(d) A film spectral sensitivity range which approximates that of type 3404 film.

Among the image recording materials investigated were:

(a) Conventional aerial black and white films

(b) Duplicating films

(c) Reversal processing films

(d) Conventional color films

(e) Kalvar and diazo type materials

Most of the above films can be eliminated from the investigation with very little consideration. The aerial black and white films will not yield the desired characteristic curve response when duplicated. Even though some

duplicating films yield favorable characteristic curve responses, the spectral sensitivity of these films is not apropos; and generally, the film speeds are too slow for use in camera systems. Color, kalvar, and diazo type materials are not capable of producing the desired transparency density range and present evaluation problems.

The film investigation showed some possibility of finding an aerial negative film that could be reversal processed to produce the desired characteristics. An experimental effort to determine a suitable aerial film for reversal processing was initiated after a literature survey of the subject.

3.2 FILM-PROCESSING EXPERIMENTATION

Several aerial negative films were selected on the basis of their resolution and characteristic curve potentialities for the experimental phase of the reversal processing study. The film list included:

1. Eastman Kodak types -
   (a) SO-206
   (b) 3404
   (c) 3400
   (d) SO-136

2. E. I. DuPont types -
   (a) SR-102
   (b) SR-104

The experiments included the reversal processing of these films in accordance with manufacturers' specifications and recommendations, and the modification of chemical formulations to correct for undesirable characteristics. In general, all Kodak film types exhibited an extremely slow film

speed; and the characteristic curves all deviated, more than desirable, from a linear relationship.

Of the two types of DuPont films, SR-102 demonstrated good speed qualities under recommended processing procedures; however, the resulting characteristic curve lacked the necessary requirements of image density range and linearity. The recommended processing procedure was modified by replacing the 129-D second developer with one of less activity, 6-D; and the first developer processing time was shortened. The film characteristic curve that resulted from the above changes in processing is depicted in Figure 3.

3.2.1 DuPont SR-102 Film Properties

The SR-102 characteristic curve indicates that the film density range is compatible with the exposure range of type 3404 film, and that all imagery contained within the linear 2.5 density range of the SR-102 film will be linearly proportional to the scene exposure. This linear relationship will assure accurate convolution of film image spread functions in the simulation process. If the master transparencies are procured in the prescribed manner of this report, the simulation of such system parameters as film imagery contrast and scene exposure can be adequately satisfied. The tone reproduction cycle, shown in Figure 4, provides a visual interpretation of these facts. Figure 5 shows the spectral sensitivity of both SR-102 and 3404 films. The shape and range of the SR-102 sensitivity curve is a good first order approximation of the 3404 curve. (This close approximation of the 3404 film spectral sensitivity distribution will enable the same spectral sensitivity range of imagery to be acquired when employing SR-102 in a camera system).

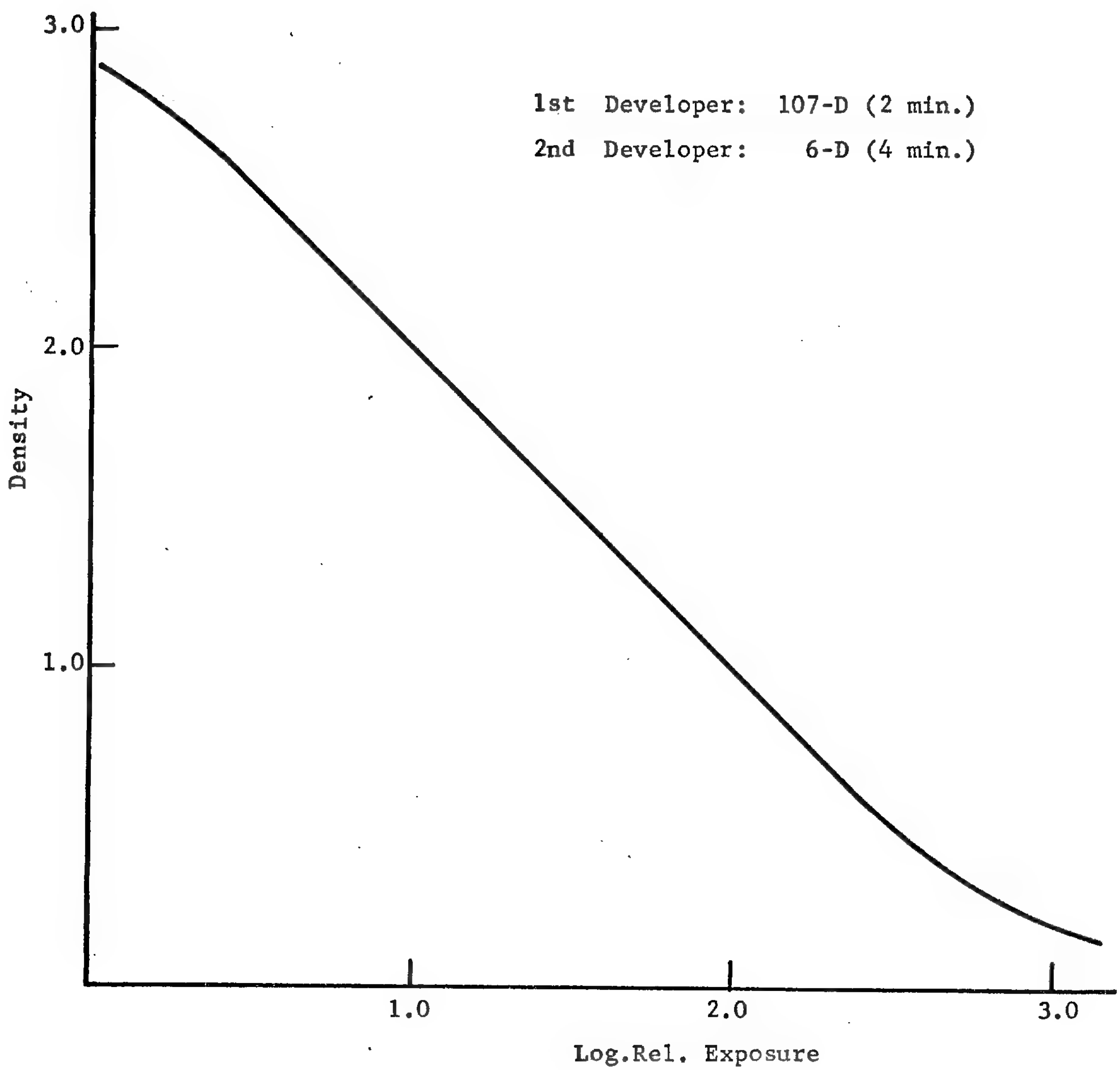

Figure 3. SR-102 Characteristic Curve

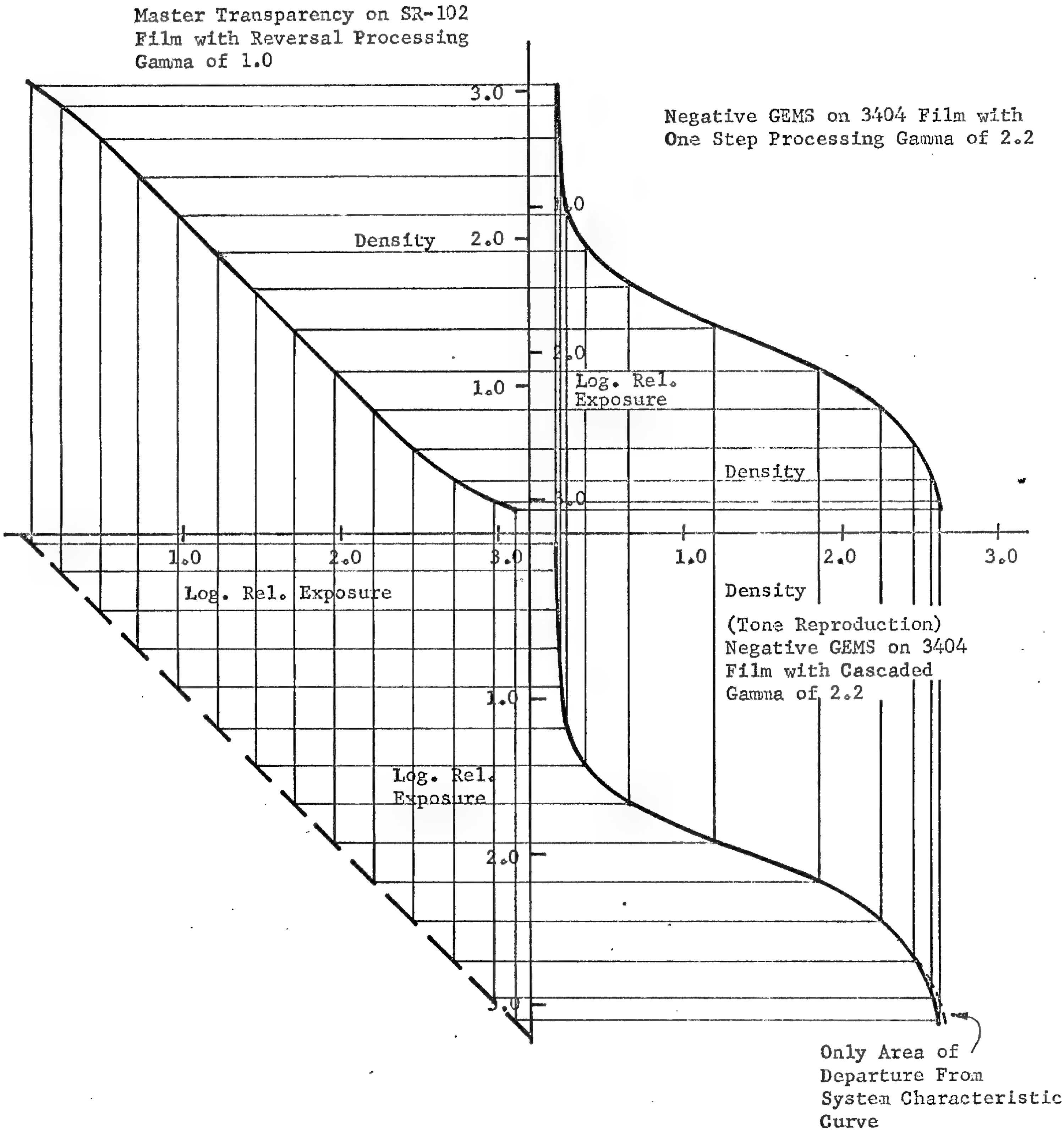

Figure 4. GEMS Tone Reproduction Cycle

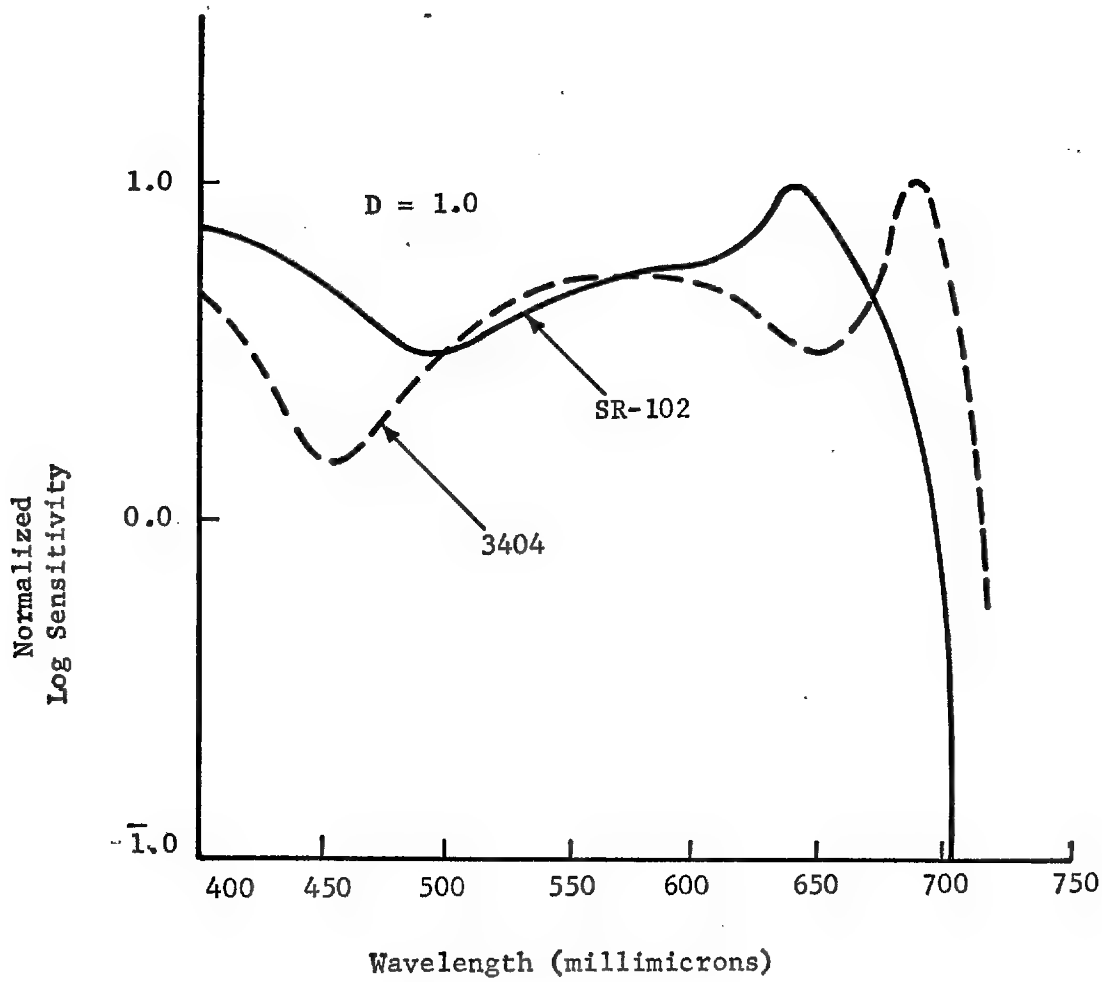

Figure 5. Normalized Spectral Sensitivity Distribution for Film Types SR-102 and 3404

Further tests were conducted with the SR-102 film-processing combinations to obtain measures of film speed and resolution capabilities. The tests revealed that the film aerial exposure index is approximately 0.8. The film showed resolution capabilities of 128 to 144 lines per millimeter based on the contact printing of a high contrast AFBT. If the SR-102 film is utilized in a camera system with good resolution characteristics, master transparencies with image quality greater than 50 cycles per millimeter should be achievable.

3.2.2 DuPont SR-102 Film Processing

Table 1 is a chart which lists the established SR-102 processing steps and chemistry. All processing was carried out in a Nikor tank with agitation obtained by inverting the tank. The agitation sequence used for the developer steps was:

(a) continuous agitation for the first 40 seconds, and

(b) 5 second agitation at 15 second intervals.

All sensitometric data reported is based upon an exposure time of 1/5 of a second in a Kodak 101 Sensitometer.

3.3 FLIGHT MATERIAL ACQUISITION

The Equal Magnification GEMS study definitely substantiates the need for acquiring flight material on DuPont type SR-102 film. The specifics associated with the material acquisition are discussed in the Flight Program Considerations report. It is sufficient to establish, herein, that the material should be obtained at an altitude of roughly 6,000 to 8,000 feet in order to photograph imagery with adequate contrast. When considering the conjugates of the modified copy camera, used in the simulation process, the width of the flight film should be 9.5 inches if GEMS of approximately 0.5 inches square are desired.

Table 1 - SR-102 Established Processing Procedure

Processing Step	Solution @ $68^{\circ}F$	Time
First Developer	DuPont 107-D	2 min
Rinse	Water	30 sec
Bleach	DuPont 3-B	50 sec
Rinse	Water	30 sec
Clear	DuPont 3-C	30 sec
Rinse	Water	30 sec
Re-exposure*		30 sec
Second Developer	DuPont 6-D	4 min
Rinse	Water	30 sec
Fix	Kodak X-ray Fix	2 min
Wash	Water	as reqd.

* Re-exposure - 2# Photo Flood in RF-2 Reflector

In concluding the film investigation, it was important to determine that the SR-102 film type could be appropriately processed in roll form. Reversal processing machines exist for processing this type film with widths of 70 millimeter or less; but, to our knowledge, no machine has been specifically designed to reversal process the 9.5 inch film width. A survey of existing processing machines revealed that two Morse Instrument Co. (type EH-7A) processing machines, employed in series, or a color processing machine would accomplish the job.

SECTION IV

CONCLUSION

4.1 SUMMARY OF STUDY RESULTS

In the Equal Magnification GEMS study, all aspects of the simulation process were examined with respect to achieving a realistic simulation of the appropriate system parameters. The study was concerned with adequately simulating the parameters of MTF, film imagery contrast, and scene exposure. The simulation is complicated by the fact that the control of these parameters is interwoven among the simulation equipment, the choice of master transparency material, and the manner in which the transparency material is obtained and processed.

The findings of the study indicate that the only physical limitation imperative to the simulation equipment is in the control of MTF above 100 cycles per millimeter. To avoid the limiting effect of Fresnel diffraction at high spatial frequencies on the modified contact printer, it is suggested that the Alternate GEMS Technique equipment be established with the use of aberration plates.

A film study and an experimental effort were conducted in order to define photographic material which would yield the following characteristics:

(a) A cascaded, unity gamma, positive transparency with a large, linear film density-exposure range for accurate simulation of MTF and adequate simulation of scene exposure,

(b) image quality greater than 50 cycles per millimeter when employed in a relatively good camera system for adequate simulation of the MTF spatial frequency range, and

(c) a spectral sensitivity distribution approximating that of Kodak type 3404 film to assure acquisition of film imagery over the same wavelength response range.

It was determined that DuPont type SR-102 negative reversal film would more than sufficiently satisfy all the requirements. The high contrast imagery requirement is to be satisfied by acquiring the flight material at a low altitude.

With the adoption of the above considerations, realistic equal viewing magnification simulations are achievable.

25X1A

25X1A CLASSIFIED MATERIAL RECEIPT

TO:

ORIGINAL TO BE SIGNED PERSONALLY BY ADDRESSEE AND RETURNED.
DUPLICATE TO BE RETAINED BY ADDRESSEE. ADDRESS: ____________
TRIPLICATE TO BE RETAINED BY SENDER.

NOTE: AVOID ANY REFERENCE WHICH WOULD MAKE THIS RECEIPT ITSELF CLASSIFIED. DATE: 11/16/67

CLASSIFICATION (SECRET, CONFIDENTIAL OR RESTRICTED)	DESCRIPTION (LETTER, REPORT, ETC. USE CODE BELOW)	DATED	REF. OR FILE NO.	ADDRESSED TO
	Two copies of Engineering Report No. 8976 (VSH-MX-007-2 and VSH-MX-007-3)			25X1A

CODE: SO – SIGNED ORIGINAL CC – CARBON COPY PC – PHOTOSTAT TC – TYPED COPY

I have personally received from the Sender Named the CLASSIFIED Documents, including enclosures and attachments, as described above. I assume full responsibility for the safe handling, storage, and transmittal elsewhere of this material in accordance with existing regulations, and it is recognized that they come within the purview of the secrecy agreement signed by:

____________ on ____________

BY: ____________
COMPANY OR INDIVIDUAL

DATE: ____________

____
SIGNATURE AND TITLE

0-0278-00

DUPLICATE

MEMORANDUM RECEIPT

4 April 1967
DATE

25X1A TO: [redacted]

FROM:

SUBJECT:

I hereby acknowledge receipt of the following:

a. H&D plot of a 1B strip read on a densitometer immediately after instrument calibration.

b. The H&D strip used in (a) above.

c. R-2 densitometer readings for [redacted] 25X1D

Please return 1 signed copy(ies) of this receipt

SIGNATURE OF RECIPIENT

25X1A To [redacted]

DATE RECEIVED

FORM NO. 752 REPLACES FORM 36-66
1 AUG 55 WHICH MAY BE USED.

(33)

25X1A

[redacted]

MEMORANDUM RECEIPT

10 August 1966
DATE

TO: [redacted]

FROM: TID/TSB, [redacted]

SUBJECT: SHIPMENT NBR. 66-XD-271

I hereby acknowledge receipt of the following:

1 each 2 condition curve Type 3404 and 3400
1 each 3 condition H&D's w/curve
2 each Processing Data Sheets
2 pkgs MX578 Developer 1 gal size
~~20 each~~ [redacted]
1 70 mm can - Sensitometric strips (3404)

25X1A

[redacted]

Please return 1 signed copy(ies) of this receipt

SIGNATURE OF RECIPIENT

To Pat

8/16/66
DATE RECEIVED

FORM NO. 752 REPLACES FORM 36-66
1 AUG 55 WHICH MAY BE USED.

(33)

File 99740 6

MEMORANDUM RECEIPT

28 uly 1966
DATE

25X1A TO: [redacted]

FROM: [redacted]

SUBJECT:

I hereby acknowledge receipt of the following:

25X1D [redacted]

sent to PE
3 aug 66

25X1A [redacted]

Please return 1 signed copy(ies) of this receipt

SIGNATURE OF RECIPIENT

To Pat

DATE RECEIVED

FORM NO. 752 REPLACES FORM 36-66
1 AUG 55 WHICH MAY BE USED.

(33)